MONTHLY PROGRESS REPORT

Contract NAS 7-352

Report No. 837-1

Col.

"PROCEDURE FOR THE DESIGN AND OPTIMIZATION

OF

A LIQUID PROPULSION SYSTEM"

Advanced Technology Center

Space Operations Division
Space-General Corporation
El Monte, California

Monthly Progress Report

"PROCEDURE FOR THE DESIGN AND OPTIMIZATION

OF

A LIQUID PROPULSION SYSTEM"

Contract NAS 7-352

Period Covered: 5 February to 5 March 1965

This

This is the first in a series of monthly progress reports submitted in partial fulfillment of the contract.

C. N. Jennings
Project Engineer

C. A. Lysdale
Program Manager

Space Operations Division
Space-General Corporation

10 March 1965

National Aeronautics and Space Administration
Western Operations Office
150 Pico Boulevard
Santa Monica, California 90406

Attention: Earle J. Sample
Contracting Officer

Subject: Contract NAS7-352/SGC 837

Reference: (a) Monthly Status Letter

Gentlemen:

In accordance with Article II.B. and Article III.B. of the subject contract, enclosed are three (3) copies of the first Monthly Status Letter Report.

The remaining copies have been distributed in accordance with the list supplied to us.

Sincerely,

SPACE-GENERAL CORPORATION

T. E. Joyce
Contract Administrator

TEJ/sgb
Enclosure: (3) Copies Monthly Status Letter Report

cc: In accordance with NASA List

1. INTRODUCTION

This report presents the accomplishments of the first month of study, and describes the work to be performed during the second month.

The objective of this study is to evolve an optimization procedure for liquid propulsion systems considering cost, reliability, performance (payload, weight, etc.) and/or development time from the overall vehicle/mission standpoint.

2. ADMINISTRATIVE

Efforts on the contract were initiated on 8 February as agreed upon during NASA/SGC negotiations. Per the effective date of 5 February (specified by the contract), the work plan and manpower and expenditure schedules for the study effort were submitted to NASA on 5 March. In order that the maximum benefit will be derived from the anticipated subcontracts with SRI and Sperry, those subcontracts will not be initiated until the study program has been more completely oriented and definition of meaningful study tasks for the subcontracts can be completed.

3. SUMMARY OF TECHNICAL RESULTS

The optimization interface approach based upon a selected system figure-of-merit has been emphasized thus far in the study to determine effects of variation in propulsion characteristics on the total vehicle/system program. Using this technique it is possible to start from the propulsion/vehicle interface and determine the effects on the "outside world" (non-propulsive components and characteristics) by varying all of the propulsion characteristics. Then with knowledge of these effects on the "outside world," the propulsion system is investigated to determine the interface characteristics which can be obtained with a given set of propulsion component design and development options. Since appreciable time during this report period has been given to more clearly understanding the merits of this approach, the following paragraphs will briefly summarize the technique.

3.1 Propulsion/Vehicle Interface

Obviously, the set of propulsion characteristics which influence the "outside world" through the interface must be complete, yet not be too cumbersome to deal with. One question which has arisen is whether the vehicle structure and any integral tankage should be considered to be on the propulsion side of the interface or on the "outside." The characteristics of these subsystems (mainly inert weight) are so interrelated with the propulsion system that they should be and can be more easily handled directly within the design of the propulsion system. However, in thinking of future applications of the optimization tool, vehicle manufacturers may not favor integral tankage and structural design criteria which have been generated by a "propulsion system optimization program." Realistically, this problem may form a "political" hindrance to general acceptance of the program which would be ideally overcome by application of a similar optimization concept to all vehicle subsystems. It is currently planned to define the optimization procedure so that it will adopt any of the various basic general tankage and structural geometries as a required input, which will then be perturbed and optimized by variation of the propulsion system characteristics. It is therefore felt that the structure and tankage will remain on the propulsion side of the interface.

The following systems will be among those included on the propulsion side or on the outside of the interface.

Propulsion System x	"Outside" of Interface
(Major Subsystems)	
Feed System	Vehicle x Subsystems
Tankage/Structure	Electrical Power
Chamber Cooling	Environmental Control
Chamber	Navigation and Guidance
Nozzle	Stabilization and Control
Injector	Instrumentation & Communication
Valves, Flow control, Throttling	Programming & Pyrotechnics
Start	Thermal Control
Ignition	Vehicle x Development
Propellant Utilization	Launch Vehicle
Control Electronics	Stage I, Stage II, etc.
Status Evaluation and Decision Equipment (READI)	Payload and Payload Support
Thrust Vectoring	Ground Support Equipment
	Launch Support

Mission limitations, constraints, and capability requirements on the propulsion and vehicle systems will be used as design inputs. These will include, but not be limited to, the following:

A. Limitations	B. Capability Requirements	C. Constraints
Acceleration	Throttleability	Development time bound
Noise	Restart	Reliability bound
Vibration	Thrust vectoring and response	Growth potential
Heating	Impulse cut-off accuracy	Spares, availability, number units req'd
Plume	Operating environment	Existing component usage
Engine Soakback	Maintainability	Fabrication facilities
Radiation	Readiness	Test facilities
Envelope	Storability (propellant combination)	Security
	Sterilization	

These inputs will have been determined from mission application studies; however, as described later, the optimization procedure can easily allow determination of the effects of these inputs on the program cost.

3.2 Figure-of-Merit

The ultimate figure-of-merit would probably be total program cost for all vehicles and missions to which the system will be applied. However, since in the optimization procedure variations in propulsion characteristics bring about changes in payload, a more realistic figure-of-merit (F. O. M.) for current project work has been selected as total program cost per pound of payload. Utilization of this F. O. M. provides an "open end" in evaluation of system characteristics, thus eliminating iteration to achieve a fixed payload weight. A lower bound of payload capability can easily be included in the analysis of the propulsion/vehicle system if necessary.

3.3 Technical Approach Using Optimization Interface Technique

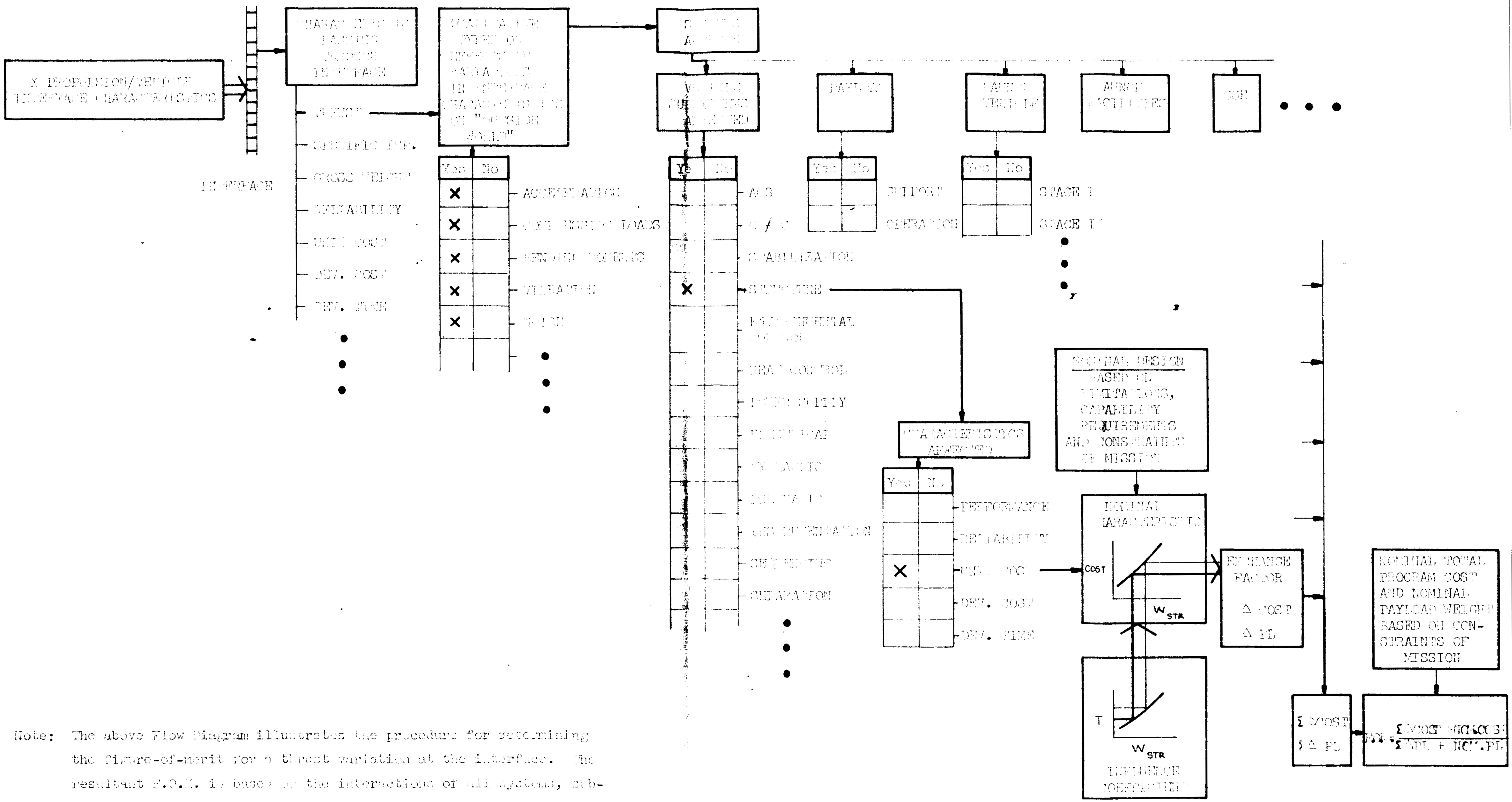
As an aid to understanding the implications and requirements associated with the selected approach, initial efforts are being directed toward working through a "sample problem" of limited scope, using grossly estimated inputs.

Initially, "nominal" propulsion interface characteristics are established based on past programs, experience, and the given mission limitations, capability requirements and constraints. Utilizing this "given" nominal propulsion system, the systems and subsystems outside the interface can be varied to establish the "nominal" design characteristics which provide the best F. O. M. - that is, the system performance, weight, cost, reliability, and development time are varied in order to determine the "optimum" design from the cost per pound of payload view point.

Next, a single propulsion interface characteristic is varied while holding the other interface characteristics constant. This establishes the interface variational effects on the nominal characteristics of the "outside world" systems and corresponding changes in total program F. O. M. (This procedure is schematically presented in Figure 1.) By varying all of the interface characteristics one at a time, and assuming the effects of varying different interface characteristics to be mathematically unconnected, the change in F. O. M. can be obtained for a range in all of the interface characteristics. The results basically form a linearized, local representation of the optimization interface surface, indicating relative advantages (Figure 2a) of increases or decreases in propulsion system cost, performance, reliability, and development time for the given application.

In the more general case, the propulsion system interface characteristics and "outside world" characteristics must be perturbed on a point-by-point basis over large variations to obtain the complete, non-linear figure-of-merit surface in an "n-dimensional" fashion (Figure 2b). However, it is easily seen that the linearized technique above will be extremely useful in initial efforts and may, in fact, be adequate for some applications of the optimization tool.

The second phase will be to investigate the available propulsion system design and development options to determine combinations of interface characteristics which are obtained with a given design. As before, the propulsion design will be established within the mission constraints for the specific application. The combination of design and development options which, when plotted on the F. O. M. graphs, give the least total program cost/pound of payload will be the best design.



Note: The above Flow Diagram illustrates the procedure for determining the figure-of-merit for a thrust variation at the interface. The resultant F.O.M. is based on the interactions of all systems, subsystems and the corresponding characteristics affected. The total [illegible] and [illegible] in the [illegible] a new F.O.M. [illegible]. Repetition [illegible] this technique [illegible] F.O.M. [illegible] for [illegible] Propulsion/Vehicle Optimization.

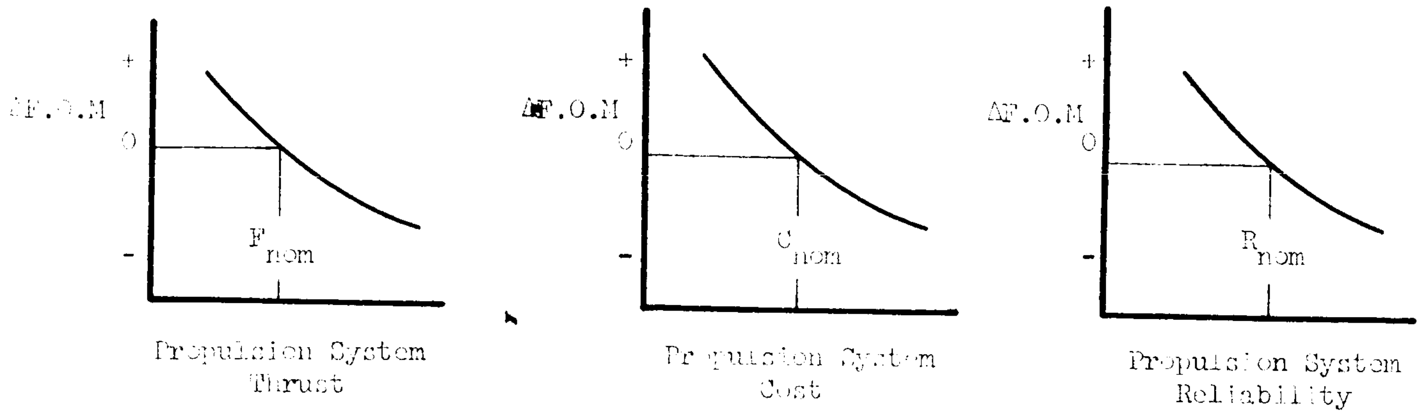


Figure 2a.

Typical "Unconnected Parameter" Approach

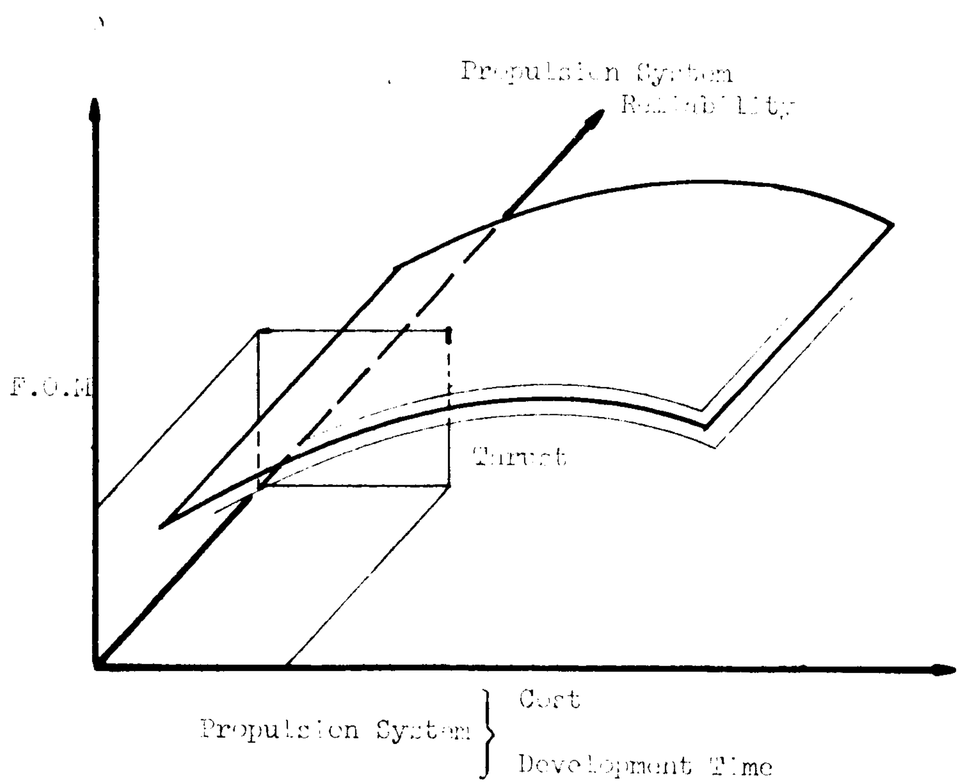


Figure 2b.

Typical N-Dimensional Approach

Studies will be conducted to determine which propulsion design options in general lead to given areas on the F.O.M. charts and which ones can or should be used to satisfy given types or levels of mission constraints and capability requirements. When all of the effects of constraint and capability variations ("specs.") on the design and development characteristics of the propulsion and vehicle systems are empirically or analytically defineable, it will also be possible to determine what a given constraint is doing to the propulsion system design and total program costs.

3.4 Propulsion and Vehicle Component Design and Performance; and Options and Alternatives

Studies and reviews are currently being conducted to establish both primary component inputs and outputs, and design influence from paths between components and subsystems. In addition, the available propulsion system design options and alternatives are being reviewed.

It is intended that the subcontract task to Sperry will include study of the application of READI (Rocket Engine Analyzer and Decision Instrumentation) system as a design alternative in the propulsion system optimization procedure.

4. PROBLEM AREAS

No major problems can be foreseen at the present time.

5. ANTICIPATED EFFORTS DURING NEXT REPORT PERIOD

Primary objectives during the next month will be to:

1. Continue the figure-of-merit approach to establish preferable propulsion design characteristics for a given mission, with emphasis on completion of the simplified "sample problem."

2. Initiate search for and development of analytical and empirical component performance, cost, reliability, and development data.

3. Undertake block-diagram type logic paths for the complete optimization procedure, based upon "sample-problem" results.

6. EXPENDITURES AND MANPOWER

The level of effort has been relatively low since the program has been in a definition phase. Total manhours and funds expended as of 5 March were approximately 350 manhours and 4240 dollars.